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COSTS AND BENEFITS OF AQUATIC WEED CONTROL,(U)
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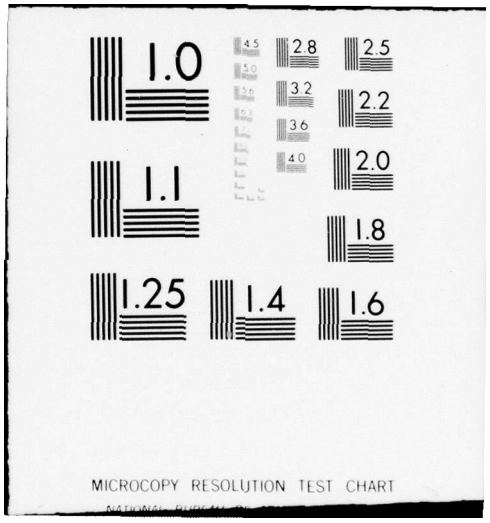
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In order to define the extent of the aquatic weed problem in terms of economic costs and benefits an attempt is made to develop order of magnitude estimates for specific damage caused by weeds in certain settings. These estimates would give a better perspective of the problem and provide guidance to which method of control to use.

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SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

The Corps of Engineers Aquatic Plant Control Program, initiated in 1899, was the first effort to control weeds by the U.S. Government. Waterhyacinth, alligatorweed, Eurasian watermilfoil and hydrilla are the primary damaging aquatic weeds. Mechanically chemical and biological weed control methods are currently being used.

Apart from losses due to weeds, it has been estimated that $5,500,000 is spent annually for treating lakes in the U.S. This amount was for treatment of only 10% of the weed infested areas.

The effects of costs and economic losses due to weeds are very severe in developing countries, such as Zambia, Thailand and Guyana, due to their limited economy, increased water demand and increased sewage effluent and other by-products of an expanding population.

Cutting cost and increasing the benefits of weed control is a major objective of the Corps of Engineers. The laws governing these programs, however, don't provide the specific standards and procedures, or other details of conducting economic and environmental evaluation; therefore, a more complete system is needed.

Benefit-cost analysis is the term given to studies by planners to assist in finding the best course of action from an economic viewpoint. It differs from routine decision-making by making use of quantitative evaluation, in monetary terms, of the goods and services expected (benefits) and the goods and services expended (costs). The benefit-cost ratio is the proportion of benefit to cost. For example, a benefit to cost ratio of 1.5:1.0 means that benefits are expected to be 150% of the cost. A B/C ratio of 1.0:1.0 means that this project will produce a rate of return equal to the benefit-cost evaluations. The higher the ratio the more justified the project should be.

Many variables and key concepts such as measurement difficulties, period of analysis, consistent pricing, etc., must be considered before a benefit-cost analysis can be performed. Even so, the analysis can be a significant, but approximate, indicator of a project's efficiency.

COSTS AND BENEFITS OF AQUATIC WEED CONTROL

INTRODUCTION

Recurring floods and doughts have been natural phenomena since prehistoric times. With the advent of man and his civilization of cities, cultivated farms and industrial development, water storage and impoundment has become a vital necessity. While it is widely recognized that aquatic weeds can cause considerable damage in these water resource areas, thereby retarding economic growth, there has been little serious attempt to quantify, estimate, or even define the extent of the aquatic weed problem in terms of specific economic costs and benefits. Therefore, a sound basis for determining the priority among competing demands on limited resources that should be given to aquatic weed control program has not been developed.

It is not possible to define economic benefits or losses in exact dollar terms. Precise information does not exist nor could it be readily developed concerning the damage caused by specific weeds in specific settings, let alone the overall impact, including secondary effects, on an economy (1). Instead, an attempt is made to develop order-of-magnitude estimates for selected types of damage caused by weeds in specific settings. Such broad estimates should at least place the problem in better perspective and provide some guidance as to the priority that should be attached to corrective action in this field.

The original effort to control weeds by the U.S. Government under the Corps of Engineers Aquatic Plant Control Program was initiated in 1899, and was accelerated and expanded in 1958 and in 1965, to achieve

progressive control and eradication of primary weed infestations of greatest economic importance in the eight South Atlantic and Gulf Coastal States from North Carolina to Texas. Waterhyacinth, alligatorweed and Eurasian watermilfoil infestations and more recently, hydrilla, are the primary problem aquatic weeds. Currently, mechanical, chemical and biological methods of control are being used. The benefit-to-cost ratio considerably exceeds the 5 to 1 estimate on the basis on which the program was authorized, in 1958 and sustains the 14 to 1 ratio determined for the following project, in 1965 (2).

The State of Florida is somewhat unique to have flood control districts with estimated costs and expenditures. A $396,000,000 system of canals, pumping stations, water reservoirs, dams, and spillways is now nearly completed for the Central and Southern Florida. This system is designed to control flooding and mitigate drought. Benefits are estimated at $82 million per year; however, they will be almost totally negated if aquatic weeds are left uncontrolled.

Drainage programs were launched in Florida in the early 1900's but they were largely underfinanced. Floods recurred, droughts were worsened by overdrainage, and hurricane driven wind tides in 1926 and 1928 claimed a total of about 2,500 lives near Lake Okeechobee. The feast and famine water cycles plagued Florida in the 1930's, 1940's and 1950's (3,4).

The Flood Control Districts (FCD) in Florida use both chemical and mechanical means of aquatic weed control. Floating aquatic vegetation, such as waterhyacinth, are killed by chemical sprays usually applied from small boats. Submersed weeds are uprooted with steel A-frames dragged

along canal bottoms by towboats, amphibious "Ducks", and other equipment. The uprooted submersed weeds float to barriers and are removed by draglines. However, the job has to be done over and over again and grows more costly every year.

In the late 1950's, the annual cost of weed control climbed above $100,000 and in fiscal year 1963, it exceeded $160,000. In 1964 it was $189,000, in 1965 and 1966, $230,000, and in 1967, the FCD expended $337,740 on weed control. From 1949 through 1967, the Flood Control District spent a total of $2,179,000 on aquatic weed control.

Within the boundaries of the Flood Control District, weed control programs are being conducted by local organizations. In the Everglades farming areas south of Lake Okeechobee, local drainage districts collect assessments of about $5/ha/yr. This money is used for local pumping operations, administration, and canal maintenance. Part of the local administration costs and much of the canal maintenance expense are used for aquatic weed control. It is conservatively estimated that drainage districts are spending at least $2/ha/yr. for these programs (5,6,7).

Watershed work areas and estimated expenditures for the fiscal year of 1978-1979 by the Corps of Engineers aquatic plant control program in the state of Florida are given in Table 1. State and local allocation of funds are given in Table 2. Costs are estimated at $1,045,798 Federal, $1,910,081 State and $4,881,749 local.

BENEFITS OF AQUATIC WEED CONTROL

Florida

With the warm sunshine and year-round growing season, aquatic weeds would soon clog all primary and secondary canals, reservoirs, and most waterways if left uncontrolled. The Flood Control Districts (FCD) would thus be unable to remove flood waters, which would inundate vast acreages. Large pumping stations operated by the Districts would be unable to pump very long before weeds were sucked into intake gratings so tightly that a head of water would be created, causing enough of a drawdown of the water level to stall the pumps.

In testimony prepared for Congress, the average annual benefits from the FCD control were ~~shorted~~ cited as a total $82,169,600. This is broken down as follows: flood damages prevented - $30,467,300; increased land use- $49,498,100; recreation - $1,794,100; fish and wildlife - $359,100; and navigation - $51,000. The water control project has a benefit to cost ratio of 4.9 to 1, which means that $4.90 in benefits are being realized in the above categories in return for every $1.00 of initial cost. This is probably one of the most generous benefit to cost ratio for any large public works project in America. (5,6).

Other benefits of the existing project include the municipal water supply and prevention of salt water intrusion; however, these have never been evaluated in dollars. Municipal water supplies and farm irrigation supplies would be seriously affected if the waterways were filled with aquatic weeds.

Navigation could be brought to a halt almost everywhere, and waterways used by fresh water fishermen would be blocked. Irrigation supplies for farmers could be drastically cut down, if not cut off. Lack of aquatic weed control would spell a nightmare of economic chaos for central and southern Florida and it is doubtful if an accurate estimate of all damages could be made. However, taking into consideration all the benefits of water control--those that have been evaluated in dollars plus those that are known to be large and significant but are unevaluated--it can be seen that values far in excess of $100,000,000 per year are at stake. With weed control as a part of water management, these are benefits; without control, the benefits would become damages. (6,7)

Florida small lakes and ponds are owned and far overshadowed in importance and use by the larger bodies of water. Numbering into the tens of thousands, they are of considerable economic and recreational importance to Florida. Economically, they provide farmers, ranchers, and growers with water for irrigation, livestock watering, and commercial fishing. Their recreational importance lies in providing fishing, swimming, and other water-based outdoor recreation.

Florida's 60 soil and water conservation districts are local subdivisions of the U.S. Government whose boundaries ordinarily correspond to county lines. Organized by referendum and chartered by the State, they are governed by five locally elected supervisors. (8) The Soil Conservation Service (SCS) provides organized districts with technical assistance in soils, engineering, agronomy, and woodland and wildlife conservation.

The Soil Conservation Service in peninsular Florida demonstrated how to grow fish in natural pond waters 32 years ago. It was possible to take ponds that had not produced good fishing in 50 years, and develop good fishing in 18 months. By chemically removing existing fish populations, and counting and weighing all fish removed, it was found that natural ponds could produce about 1,000 kg/ha. The lowest weight was taken from a pond in poor sandy soil; the highest weight came from a very fertile farm pond. It was found that the total number of fish a pond would suppot was dependent upon the water's fertility and fish stocking procedures. As a result of this work, farmers, ranchers, and growers in Florida's soil and water conservation districts stocked and have under management more than 8,000 small farm ponds.

Most of these farm ponds had or have aquatic weed problems, a situation which generally leads to poor fish production. The weeds form such a tangled mass of vegetation that it is difficult or impossible to fish or even paddle a boat. Additionally, small fish (particularly bluegill) are protected from the larger fish. The pond then becomes overcrowded with small bluegill, which are stunted and never grow to any size. Floating plants, such as waterhyacinth (Eichhornia crassipes), water lettuce (Pistia stratiotes), salvinia (Salvinia rotundifolia) and the duckweeds (Lemna minor) exclude sunlight from the water, thus causing a chain reaction that eliminates oxygen from the water (9,10).

Although there are hundreds of thousands of wetland acres in Florida, many are useless because of aquatic weeds - few of which are of value to waterfowl. In north Florida, wild ducks and geese have abandoned lakes

and marshes containing aquatic weeds and are using manmade duck fields; the planted choice food is corn and millets flooded by water control measures to a depth suitable for feeding.

Seeking more efficient use of land devoted to the production of food and fiber, Florida's farmers, ranchers, and growers have sought to equalize the vagaries of the annual rainfall pattern. Soil Conservation service engineers have assisted them in the design of V-type field ditches intended to control water flow. Subsurface irrigation is practical and effective in porous sandy soils where a high water table exists. The Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress) was signed by President Eisenhower on August 4, 1954. To date, sixteen small watershed projects have been authorized in Florida. They cover more than 500,000 hectares, with an estimated total cost of more than $29,000,000 (11).

Louisiana

Computing figures to compose the benefit statistic is very much like computing related economic values (12). The client population which receives direct benefits from the aquatic weed control program include fishermen (sport and commercial); trappers; waterfowl hunters; individual boat owners; shoreline property owners; municipalities which depend on lakes and reservoirs for domestic water supply; individuals whose livelihood depends upon service to listed benefactors-- i.e., recreational equipment manufacturers and distributors, resort owners, etc.; and water oriented recreation participants -- i.e., swimmers, canoers, campers, picnickers, skiers, etc. This population is estimated at 2,311,740 as given in Table 3.

The client population which receives indirect benefits from the aquatic weed control program include: nearly all agricultural interest that is dependent on aquatic weed control to maintain channels for irrigation and drainage; residents of low lying parishes for flood control drainage; oil companies which operate in inland aquatic situations; commercial navigation and water transport interest: commercial industrial plants and generating facilities which depend on water from reservoirs and streams for cooling and fire protection; general public health from the reduction of areas which harbor insect pest and vectors of human diseases. This client population is conservatively estimated at 250,000 additional individuals. Louisiana has a population of approximately 3.5 million people. It is estimated 2,561,740 individuals of this population receives benefits from the aquatic weed control program conducted by the State.

Texas

Texas has had water hyacinths in Lake Corpus Christi, a lake of 10,000 ha near the southern Gulf Coast since 1935. Here plants were introduced by well meaning but un-informed people who though they were an attractant for waterfowl. Work on Lake Corpus Christi near the city of the same name began in 1952 with the advent of our Dingell-Johnson program to State agencies. This first work to erradicate waterhyacinths was erratic, piece-meal, poorly planned and restricted to the warm months of the year. Consequently these efforts served only to reduce the plants prolific reproduction some extent, without making any headway into large scale plant removal. In 1961 spraying with aquatic herbicides was prohibited by

Federal regulations and work on this important aspect unfortunately had to be halted. From 1961 to 1969 this area of infestation grew from the remaining 300 ha to approximately 5,000 ha of waterhyacinths. These green masses prohibited boat traffic, furnished breeding grounds or mosquitos, reduced lakeside land values, increased potable water losses by trans-evaporation, and brought staggering economic losses to camp operators.

Since March, 1970, when the Parks and Wildlife Department of the State of Texas entered into a contract with the U.S. Corps of Engineers over 7,000 ha of waterhyacinths have been removed from the Nueces Watershed, principally from Lake Corpus Christi. This plant removal was performed with a government approved formulation of 2,4-D for use in potable waters. Part of the job was accomplished by aerial application, shoreline truck units and shallow water craft, but the major portion of the work was performed by using specially designed deep water boat spraying units. It became mandatory that some plant eradication work be done in this area because boat traffic was not possible over many parts of the lake, floating waterhyacinth mats prevented any type of trotline fishing. Many good black bass areas were closed in by plants, lakeside home owners could not launch their boats, and the plants trans-evaporation processes were reducing the available drinking water supply to a precarious level.

The preliminary phase of the eradication work encompassed 5,000 ha of plants. These plants reduced fish populations by competing for available water space, which resulted in the over-abundance of small undesirable fish. Consequently this led to diminished use of public fishing and

recreation waters. Recreational values based on fisherman expenditures and usage for this area amounts to $1,240,000 per year. Recreation value on the basis of 50¢/day for 80,000 man-days per year amounts to an additional $40,000 for the year. Hunting revenue for this area is low because there is not much waterfowl activity present, but this phase does add $6,250 per year. Also the usage of the lake and surrounding area by sight-seers, bird watchers and hikers gives another $10,000 to the benefits. Our total recreational benefits on the base of the 4,000 ha of plants removed amounts to a grand total of 1,296,250 per year.

Seldom do we include the benefits accruded to real estate and land values in our reports. However, plant removal is not an easy matter and money must be spent to realize that goal. In the Nueces Watershed Project, the property owners of 200 miles of shoreline benefited by at least $50/ha. This would have a total benefit of $3,200,000 per year.

The conservation of water is rarely considered. The water saved from trans-evaporation on Lake Corpus Christi, is enough to furnish 20,000 gallons of water per month to 108,900 households for one year. Assuming water treatment, and purification to be 75% of cost this would amount to a savings of $1,361,125 per year or a grand total of $4,632,375/year benefits from the control program.

United States

Apart from losses due to aquatic weeds, it has been estimated that about $5,500,000 is spent annually for treating lakes and ponds in the U.S., and this amount of money was for treatment of only approximately 10% of the weed infested areas. In 17 western states in 1957, 95,000

kilometers of canals were treated for aquatic weeds which represented 54% of the aquatic weed infested area (13,14,15).

Rather elaborate calculations of the annual benefits of the Expanded Project for Aquatic Plant Control (14) in the States of Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina and Texas have been compiled:

Flood and control and drainage (urban)	$ 580,000
Water and flood control (agriculture)	3,590,000
Fish and wildlife	3,310,000
Recreation	3,600,000
Mosquito control	170,000
Water supply	100,000
Pollution control	2,610,000
Total Annual Benefits	$13,960,000

In addition to these estimated benefits, which appeared to be very conservative, attention is called to the fact that if there had been no control program the area of infestation would have grown from 90,000 ha in 1959 to 150,000 ha in 1963. The cost for treating 50,000 ha amounted to $187,600 or an average cost of $15.15/ha is benefits of $15.15/ha.

ECONOMIC IMPACT OF AQUATIC WEEDS

The damage and problems caused by weeds can have in varying degrees a negative effect upon a country's economy. Whereas a developed country, such as the United States, can readily absorb such economic losses, as has happened in Florida, Louisiana, Mississippi, and Georgia, such losses cannot be easily accepted in a developing country. Countries which have

only one, or a few, waterways or other fresh water bodies can be more seriously affected than "wetter" countries, with much fresh water and an extensive riverine network. In countries straddling or bordering the Niger, the Congo, or the Nile rivers, for example, weeds can be a very serious potential threat to the overall economy. Even in the "wetter" countries such as Ceylon, India, Guyana, and Brazil with many ancillary waterways, massive weed infestation will, with time, have measurable economic consequences, especially where the major rivers are prime avenues for transportation, for sources of food, or for hydropower. The economic loss resulting from disease is particularly difficult to assess, even in societies where collection of complete and accurate demographic and social data is a well established practice.

Some attempts have been made to assess the impact of weeds upon the economies of Florida and Louisiana which may give some baseline for estimating losses and developing countries. Even as far back as the turn of the century, when the embryonic hyacinth infestation plagued Florida with Lake George being blocked by hyacinths for 40 kilometers, an annual loss to the lumber trade alone of $55,000 was estimated. Transport by water is still a vital factor in the economy of the Mississippi delta, since corn, rice, cane and cotton, together with fish, citrus fruits, salt, oil, lumber and other products, are all carried by water. The waterhyacinth invasion has thus had serious consequences, and it has been estimated that the annual loss incurred in Louisiana through the effects of the weed reached $35 million annually in recent years from damage to agriculture, fish and wildlife, navigation, drainage, and public health.

Aside from such roughly estimated direct economic losses, there are additional costs of deliberate weed removal and prophylactic measures for growth prevention. Such costs, which may amount to millions of dollars per year, are incurred just to keep the weeds under some level of control and prevent further economic damage. Since 1959 the Corps of Engineers in Florida has received about $3.6 million annually for waterhyacinth eradication programs in Florida to which is added a 30 percent matching contribution by the State. In addition, in 1969, the State of Florida spent $1.3 million for control efforts, and for fiscal year 1970, $2.5 million was expended.

The economic losses estimated for the United States are, at best, rough estimates prepared by Federal, State and local organizations concerned with budgets. While these estimated dollar losses represent the principal "hard" data available for any country, they are difficult to apply directly to developing country situations, with different labor and other costs and differing methods of estimating costs. For example, with regard to water transport, the large motorized barge systems used in the United States are less sensitive to cooling-intake clogging and propeller fouling than are the small, individual, and relatively crude river steamers and small barges powered by outboard motors so commonly used for transporting goods in developing countries.

In developing countries considerable sums are spent for weed control. In most cases at least one half of the funds draw on scarce foreign exchange to pay for cutting apparatus and chemicals. Furthermore, needed labor for dam construction, flood control, fishing and transportation is

often idled as the control programs are carried out or must be used for weed harvesting or destruction. The uranium and copper mining interests in the Congo Republic are known to have spent millions of dollars in this field. Egypt and the Sudan each spend about $1.5 million annually on control programs.

In the Sudan, an initial hyacinth control program involving technical advice, organization building, appropriate equipment and supplies, and control operations, was supported by USAID from 1960 to 1964. At the conclusion of the project, weed control activities employed 73 river craft of all types, 28 vehicles, 5 planes, 500 full time employees and 500 seasonal laborers. Control was effected largely by 2,4-D herbicide deployed from boats, land-based spray vehicles, and man-carried sprayers, as well as from aircraft under favorable weather conditions (16).

COUNTRY SPECIFIC SITUATIONS

All available reports agree that aquatic weeds present "serious economic problems" for developing countries and that these problems will increase unless major control measures are undertaken. An attempt has been made to translate the weed menace assessments into very broad and quasispeculative dollar equivalent losses. Several developing countries were selected as reasonably representative of those suffering economic losses which seem to have a measurable impact upon their economies. Principal attention is directed to losses due to constraints on transportation and fishing which are the easiest aspects to address in a quantitative manner (17,18,19).

Zambia

The inadequate road and railroad network of this landlocked country forces dependence on short-haul water transportation on the Zambesi, Kaufue, Luangiva, and Chambesi Rivers and Lakes Tanganyika and Kariba for internal commerce. The presence of rapids and varying seasonal depths of water inhibit long-haul river transport although logs and other freight are transported on the Zambesi above the falls at Livingstone. Trade with Rhodesia across Lake Kariba is limited. For at least eight months of the year, these bodies of water are infested to some extent with aquatic weeds restricting water-borne transportation.

The effect on internal commerce is significant. Considering agriculture, forestry, and fishing only, a two to three percent impact due to blockages of waterways and fishing areas means an internal loss of commerce of several million dollars since these sectors account for more than $75 million of the country's total commerce. Weed clearance schemes, including reliance on imported equipment and materials, add another $750,000 to $1,000,000 in costs annually. In addition, schistosomiasis has shown a 10 percent increase from 1965 to 1969, which may be related to the presence of aquatic weeds.

Thailand

The lower Mekong River Basin, as well as other riverine regions in Thailand, with their reservoirs, ponds, inlets, and channels, is infested with hyacinth, water lettuce and water fern. Very roughly, about 30 percent of the Thai labor force is engaged in activities related to fishing and river transport. Fresh water fish serve as an important food

source, with the rice fields and irrigation channels serving as good breeding grounds. There are important river and canal networks used for boat transportation around Bangkok and in the delta. There is evidence that weed infestations are growing steadily and are beginning to have a noticeable influence on river transportation and fishing. In the Nam Pong and other reservoir areas the weeds are moving downstream where they accumulate in reservoir impoundments, and grow at an accelerated rate. While the economic consequences are difficult to quantify, order of magnitude estimates of the severity of the problem are presented below.

More than 80 percent of the rice crop, which earned $121,000,000 in foreign exchange in 1970, moves over the many waterways. Similarly, about 30 percent of the tin ore, tungsten ore, corn, sugar cane, rubber, and other export products move by water. The approximate value of such watershipped products is about $300,000,000 per year. Assuming weed clogging reduces the mobility of boats and barges so that about two percent of the potentially marketable products do not arrive at their destination at all or too late, then an annual loss of several million dollars accrues, including a substantial foreign exchange component.

The annual fresh water fish catch is valued at about $100,000,000. With the weeds interfering with spawning, a one percent loss could cost the economy $1,000,000 per year. The actual loss is probably greater since the weeds interfere with fishermen's gear and boats, and they probably also harbor fish predators.

With regard to costs of preventive action, it is estimated that initial herbicide weed control in the Pa Mong dam site area would cost about $50 per hectare and would be required for 10 percent of the

reservoir area, and an additional $40 per hectare per year for one percent of the area to prevent weed encroachment. It is also estimated that a weed control research team costing $200,000 annually would be needed for 10 years to cover the delta region. If the same control and prophlactic costs were to accrue for other-than-delta waters, and assuming that about 1,000,000 hectares are threatened, then a probable initial cost would be several million dollars and annual expenditures would reach about $400,000.

Schistosomiasis is of growing concern in the Mekong region. The toll of this disease on the economy is not known. It is reasonable to estimate that the weeds could add one percent to the incidence of the disease which probably afflicts several million people. Assuming a 10 percent loss in productivity of the afflicted, it seems clear that from this point of view the weed menace is significant.

Guyana

This small developing country suffers from both actual and potential aquatic weed infestations, mostly from the waterhyacinth. Guyana has 3,700 miles of navigable waterways which are the only transportation routes. River fishing and forest products, which are heavily dependent on river transport, account for about 12 percent of the Gross National Product (GNP). The country, with a GNP of about $235 million, cannot afford any interference with the flow of export foods and materials amounting to $121 million, with about 20 percent moved by river. A one percent weed-caused loss in river dependent exports seems conservative, given the extent of the weed problem. This means a $250,000 per year loss -- a modest but nevertheless serious item for a country with a trade

deficit. Assuming that weed control would cost about $100,000 annually, a $350,000 per year loss accrues -- and most of it in greatly needed foreign exchange. Mosquito-borne diseases have been a long time concern of the country. While malaria has been almost eliminated, weed infestations may cause a recurring control problem because the mosquitoes which breed in the weeds are very difficult to eradicate. Some schistosomiasis increase has been reported, and it is likely that the increase is related to weeds (20,21,22).

In the sense that aquatic weeds constitute a crop of potential use, much research has been done during the past fifty years to find economic means of utilizing them as commercial products. These efforts have been summarized by an advisory committee of the Office of Science and Technology for the agency for International Development in cooperation with the National Academy of Sciences. While it is possible to discuss these alternatives in terms of potential application, there are no practical applications that can be cited except herbivorous animals, and these have had very limited economic impact on the total problem (23).

METHODOLOGY OF COST-BENEFIT ANALYSIS

A major objective of the programs of the Corps of Engineers has been the efficient utilization of resources in the resolution of problems and satisfaction of needs whether of a national, regional or local nature. The basic laws governing these programs, however, do not provide the specific standards and procedures, or other required details of conducting economic and environmental evaluation. Broad general policy, has been

provided legislatively throughout the long history of the program by such legislation as P.L. 93-251, the Water Resources Development Act of 1974; P.L. 92-500, the Federal Water Pollution Control Act Amendments of 1972; P.L. 91-611, the Flood Control Act of 1970; and P.L. 91-190, the National Environmental Policy Act of 1969.

It is obvious from these legislative directives and objectives that the process of project or program formulation necessarily must be a process of identifying, assessing, evaluating, and comparing alternatives for meeting specific objectives to determine their relative merits in satisfying human needs. By this process of comparison the alternative which provides for the needs in the most acceptable manner can be more realistically selected and tested for justification (24,25,26).

Benefit-cost analysis is the term given to the studies made by planners and decision-makers to assist in selecting the best course of action from an economic viewpoint among a number of alternatives. It differs from routine judgement and decision-making by making use of quantitative evaluation, in monetary terms, of the goods and services expected (i.e., benefits) of an action and the goods and services expended (costs) in undertaking an action. The benefit-cost ratio is the proportion, expressed as a simple numerical fraction, that the benefits bear to the costs. A benefit-cost ratio of 1.5:1.0 means that benefits are expected to be 1-1/2 times or 150% of the costs, under the assumptions used for the study. A project having a B/C ratio of 1.0:1.0 means that benefits are expected to equal the costs under study assumptions. This is equivalent to saying that such a project will produce a rate of return

equivalent to the interest or discount rate used in the benefit-cost evaluations.

A project is considered to be justified and properly formulated when (1) project benefits exceed project costs; (2) each separable increment or purpose provides benefits at least equal to its related incremental costs; (3) the scale of development is such as to provide maximum excess benefits over costs and (4) there is no more economical means of accomplishing the same purposes which would be precluded from development if the project were undertaken. The determination process, accordingly, entails the measurement of benefits and costs on a with and without project basis. The comparison of the differences in benefits and costs between these conditions is commonly referred to as the benefit-cost ratio. Since the derivation of this ratio is not an exact science many contentions have been made in the past regarding its value in the decision process. Experience, however, demonstrates that it is a useful, realistic means of appraising quantifiable effects of water resources proposals and further, of comparing those effects with subjective views pertaining to the unquantifiable effects. In this manner the tradeoffs between the beneficial and adverse effects can be identified. The analysis is considered to provide a logical framework for the evaluation of various courses of action (1).

Fundamentally, planning and evaluation relates to the need to identify the optimum use of public resources. This necessitates searching for a course of action which maximizes benefits relative to total costs - economic, social, and environmental. Naturally, a variety of needs may be

met by projects (or programs) of widely different dimensions. The mere fact that one alternative offers more net benefits than another is not sufficient proof of its economic desirability. The proper criterion of comparison, therefore, must be expressed in relative terms. Benefit-cost ratios which can be used to economically describe or weigh different alternatives have, therefore, been applied as one major criterion to assist decision-makers in choosing among proposed public investments. Using this approach, if it can be shown that the total benefits of a given project exceed its total cost, it may be said to have passed the minimum test of economic feasibility. If this is the only possibility in which the planning objectives as a reflection of study area needs and problems identified by the public can be served, then the proposed project will also be the most economic alternative. However, all feasible alternatives must be considered. Only that project with the maximum excess of benefits over costs among the various alternatives considered is the most economically desirable. Benefit-cost analysis thus provides decision-makers with a useful mechanism for ranking these several projects in their order of economic merit. To say this, however, is not to imply that all public investment decisions should be made strictly on economic grounds. Clearly, many concerns, not necessarily economic, may be overriding. The major, if not exclusive, area in which the benefit-cost test has been widely applied has been in the Federal program for water resources development.

Background and Evolution

The original requirements for benefit-cost comparison are considered to be implicit in a Flood Control Act in 1850, authorizing a survey for "...determining the most practical plan..." and a 1909 Act which required "...that Congressional reports give increased detail on...project benefits...scope of projects and the basis for Federal participation." However, it was not until passage of the Flood Control Act of 1936 that Congress adopted a nationwide policy for flood control and, for the first time in major public legislation, set forth the important specification that project "benefits to whomsoever they accrue" be in excess of estimated costs. The 1936 Act, accordingly, may be taken as the essential point of departure for modern-day benefit-cost evaluation. It resulted in adoption by the Corps of a formal, continuing policy of applying benefit-cost analysis to all proposed projects submitted for consideration of the President and the Congress. However, the presently applied method of benefit-cost analysis did not spring into being overnight; instead, it represents a method, a procedure, and an approach to analysis of proposed public water resource projects which has continuously evolved from inception of the program with advances in economic theory, improvements in techniques of data gathering and assimilation, and substantial empirical experience.

The 1950 interagency report entitled "Proposed Practices for Economic Analysis of River Basin Projects", provided a systematic treatment of benefit-cost practices then in use. The report, prepared by an Inter-Agency Committee on Water Resources, was an objective analysis of

the economics of river basin projects uninfluenced by those practices or by legal and administrative limitations.

Drawing on much of the work contained in that report, the then Bureau of the Budget issued its Budget Circular A-47 on 31 December 1952. Basically, Budget Circular A-47 informed the Federal water resources agencies of considerations which would guide the Bureau in its evaluations of projects and of the requirement for uniform data that would permit comparisons among projects. Projects were mainly to be evaluated on the basis of primary benefits clearly identifiable as gains, assets or values directly resulting from the project. Recreation and fish and wildlife benefits were to be treated as incidental.

The Budget Circular A-47 standards were replaced in 1962 by "Policies, Standards, and Procedures in the Formulation, Evaluation and Review of Plans for Use and Development of Water and Related Land Resources", approved by the President on May 15, 1962, and published as Senate Document 97 (SD 97), 87th Congress, 2nd Session. That document expanded the dimensions of water resource planning objectives by instructing the agencies to consider national, regional, State, and local viewpoints in planning. The objectives of planning were stated to be the following:

A. National Development, including development of each region within the country.

B. Preservation, or the concern with environmental quality.

C. Well-being of all the people as the overriding determinant in considering the best use of water and related land resources.

The overall basic objective of SD 97 was to provide the best use or combination of uses of wate and land resources to meet both short term and long-term needs.

Under SD 97, both primary and secondary tangible benefits, based on monetary yardsticks, and intangible benefits, based on satisfying human needs and desires, were to be considered in determining total benefits of a project. Provisions stressed in that Document included consideration of outdoor recreation and fish and wildlife development as equal to such historic purposes of project development (27,28,29).

Limitations in Practice

Increasing recognition of the difficulties regarding the operability or limitations on SD 97 with regard to emerging environmental concerns, as well as the change in the discount rate formula, led to the creation by the Water Resources Council of a Special Task Force on Evaluation Procedures in November 1968.

The final report of this Task Force, issued in August 1970, recommended a broad multiobjective approach to water resources planning identifying the co-equal national objectives in attaining such planning as being four, namely:

--National Economic Development

--Environmental Quality

--Social Well-Being

--Regional Development

Subsequently, the Water Resources Council, with the approval of the President, formally issued the Principles and Standards as guidelines for the planning and evaluation of Federal water and related land planning. These became effective on 25 October 1973.

The new guidelines provide for consideration of two, rather than four, national objectives, namely:

--National Economic Development

--Environmental Quality

At the same time they provide for a system of public information accounts. In addition to the above two objectives, two non-objective accounts are to be reflected in project considerations, namely - Social Well-Being and Regional Development.

SOME KEY CONCEPTS IN BENEFIT ANALYSIS

Discussion of a few key concepts is essential in providing a basic understanding of benefit-cost analysis.

Market Simulation. Basically, benefit-cost analysis represents a simulation of the operation of a competitive market economy to provide a basis for the allocation of resources in sectors where, for any of several reasons, the market mechanism may not function properly. In cases, the private sector will not undertake investments because projects are so large that only a public agency can undertake them or because there is no effective way that beneficiaries can be charged for the services rendered. For example, with regard to problems of water pollution downstream, damages are difficult to identify and quantify and charges are even more difficult to levy on those who cause them.

Measurement Difficulties. Many benefits from social investments, including research and development, present complex problems of measurement in economic terms. For instance, Corps research and development activities in recent years have undoubtedly resulted in substantially improved efficiency in project formulation as well as associated project economies, but precise measurement of these advances is exceedingly difficult.

Alternative Cost. An appreciation of the concept of "alternative cost" is basic to clear understanding of benefit-cost analysis. When goods and services are utilized for the purpose, of a major economic impact, that action is to preclude their employment in alternative uses. Thus the values that would have resulted from alternative uses are not the true economic costs of the resources used in a project. Thus defined, the annual cost of a project is parallel and comparable to its annual benefits, and the resulting comparison of efficiency is between two annual volumes of economic output. If a benefit-cost ratio is greater than unity, the output of goods and services is increased by diverting resources from other uses to the construction and operation of a project.

Period of Analysis. The period of analysis is the shorter of either the physical life or the economic life of the structure, facility or improvement. A period of 100 years is normally regarded as the upper limit for large reservoirs, major long-term urban flood protection projects, and for mainline levee protection projects. For all other types of projects a 50 year period of analysis is generally used.

Consistent Pricing. The development of product and service prices and their application to the products and services expected from a project, is another essential element in benefit-cost analysis. Uniform pricing concepts are required in order to realistically use benefit-cost analysis in the formulation and selection of projects. If the output of one project purpose is over-valued in relation to the outputs of other purposes, the project cannot be formulated properly, [redacted]. Thus, a project which is economically acceptable at a "low" discount rate, may be economically precluded at a "high" discount rate. The specific interest rate to be used is specified annually by the Water Resources Council (U.S. Government). Under the existing formula it represents the average yield during the preceding fiscal year on interest-bearing marketable securities of the United States, which, at the time the computation is made, have terms of 15 years or more to maturity.

PROJECT BENEFITS

Benefits are the increases or gains, net of associated or induced costs, in the value of goods and services which results from conditions with the project, as compared with conditions without the project. There are tangible and intangible benefits and these may be classed as primary or indirect (secondary).

Tangible Benefits are those benefits that can be expressed in monetary terms based on or derived from actual or simulated market prices for the products or services, or, in the absence of such measures of benefits, the cost of the alternative means that would most likely be utilized to provide equivalent products or services are called tangible benefits.

Intangible Benefits, on the other hand, are benefits which, although having real value in satisfying human needs or desires, cannot be satisfactorily expressed in monetary terms.

In general, benefit measurement--tangible and intangible--encompasses consideration of a number of factors.

a. Direct Outputs. The objective of primary benefit analysis is to determine increases, net of associated or induced cost, in the value of goods and services which result from conditions with the project, as compared with conditions without the project.

b. Market (demand price). Where the market is considered reasonably adequate and competitive, the value of outputs should be based on probable exchanged values as measured by the market prices expected to prevail at the time of project construction. If the additional project output is expected to change market prices, a price midway between that expected with and without the plan may be used to estimate the total value. The market value for certain principal agricultural commodities is specified by the Water Resources Council.

c. Non-Market. In the absence of an adequate competitive market, the expected costs of production by the most likely alternative source that would be utilized in the absence of the project may serve as a basis for measuring the value of goods and services. Where recreation benefits are considered, they are based on simulated market values.

d. Indirect. In national income evaluation the Corps does not normally attempt to place monetary values on the more extended benefits of a project such as stimulation of business activity, effects of business

activity and effects of increased agricultural activity beyond the farm. The rationale is that similar secondary effects would in all likelihood result from some other use of the goods and services necessary for the project.

e. Non-Monetary or Intangible Benefits. Because of inherent measurement difficultties, this class of benefits has seldom been fully evaluated in significant detail in Corps analysis. Some of these benefits, such as the prevention of loss of life, can be more or less estimated in terms of physical units but cannot be converted to monetary values. Other benefits, such as improved scenic beauty, are difficult to quantify at all. It is generally recognized that these and similar benefits may and often do result from a water resources project. The question is--should these benefits be evaluated? There is substantial agreement that intangible benefits are important and that they should be considered in plan formulation and evaluation.

It is recognized that intangible benefits are real, may be extremely important, and may even warrant approval of a plan that is not justified on the basis of net tangible benefits alone. Some of the intangible benefits considered by the Corps are prevention of loss of human life, environmental quality, enhancement of the general welfare and security of people and improvement of sanitation and protection against epidemics of fundamentally important public health measures. If intangible effects are significant then basing plan formulation solely on maximization of net tangible benefits may lead to socially undesirable decisions. Thus,

project formulation should be directed towards achieving the best possible use of resources involved, not just toward/maximizing net tangible benefits.

f. Benefits to Selected Purposes.

(1) Flood control and prevention benefits: Reduction in all forms of damage from inundation of property, including sedimentation, disruption of business and other activity, hazards to health and security, and loss of life; and increase in the net return from higher use of property made possible as a result of lowering the flood hazard.

(2) Navigation benefits: The principal benefits utilized in the justification of navigation projects are transportation savings. The unit savings are measured as the difference between the rates shippers are actually paying for transportation via the alternative mode at the time of the study and the rates they would pay via the improved waterway. The estimates of savings are developed by comparing the full charges for movement from origin to destination via the prevailing mode of transportation with the full charges via the waterway being studied. Navigation improvements may also provide benefits in other forms, such as reduction in losses due to hazardous or inadequate operating conditions and enhancement in land values from the placement of dredged materials. The U.S. Congress has provided the standard for computing beneficial effect, of navigation in Section 7(a) of the Department of Transportation Act of 1966.

(3) Electric power benefits: The value of power to the users is measured by the amount that they should be willing to pay for such power. The usual practice is to measure the benefit in terms of the cost of

achieving the same result by the most likely alternative means that would exist in the absence of the value of savings in the non-renewable resources.

(4) Recreation benefits: The value as a result of the project of net increase in the quantity of boating, swimming, camping, picnicking, winter sports, hiking, horseback riding, sightseeing, and similar outdoors activities. In the general absence of market prices, values for specific recreational activities may be derived or estimated on the basis of a simulated market giving weight to all pertinent considerations. This would include charges that recreationists should be willing to pay and to any actual charges being paid by users for comparable opportunities at other installations or on the basis of justifiable alternative costs. Benefits also include the intangible values of preserving areas of unique natural beauty and scenic, historical, and scientific interest.

(5) Water quality control benefits: The net contribution to public health, safety, economy, and effectiveness in use and enjoyment of water for all purposes which is subject to detriment or betterment related to water quality. The net contribution may be evaluated in terms of avoidance of adverse effects which would accrue in the absence of water quality control, preclusion of economic activities, corrosion of fixed and floating plant, loss or downgrading of recreational opportunities, increased municipal and industrial water treatment costs, loss of industrial and agricultural production, impairment of health and welfare, damage to fish and wildlife, siltation, salinity intrusion, and degradation of the esthetics of enjoyment of unpolluted surface waters,

or, conversely, in terms of the advantageous effects of water quality control with respect to such items. Effects such as these may be composited roughly into tangible and intangible categories, and used to evaluate water quality control activities.

(6) Domestic, municipal, and industrial water supply benefits: This includes improvements in quantity, dependability, quality, and physical convenience of water use. The amount water users would be willing to pay for such improvements in lieu of foregoing them affords an appropriate measure of this value. In practice, however, the measure of the benefit will be approximated by the cost of achieving the same results by the most likely alternative means that would be utilized in the absence of the project. Where such an alternative source is not available or would not be economically feasible, the benefits may be valued on such basis as the value of water to users or the average cost of raw water (for comparable units of dependable yield) from municipal or industrial water supply projects planned or recently constructed in the general region.

(7) Beach Erosion Control benefits: Control or prevention of beach erosion may include tangible primary benefits from physical damages prevented, emergency and business costs avoided, enhancement of property values, and increased recreational usage. Benefits should be measured as the differences in these values under conditions expected with and without the proposed erosion control measures.

(8) Fish and wildlife benefits: The value as a result of the project of net increase is measured in recreational, resource preservation, and commercial aspects of fish and wildlife. In the absence of market prices,

the value of sport fishing, hunting, and other specific recreational forms of fish and wildlife may be derived or established in the same manner as prescribed for recreation. Resource preservation includes the intangible value of improvement of habitat and environment for wildlife and the preservation of rare species. Benefits also result from the increase in market value of commercial fish and wildlife less the associated costs.

(9) Irrigation benefits: These are measured by the increase in net income of agricultural production resulting from an increase in the moisture content of the soil through the application of water or reduction in damages from drought.

(10) Drainage benefits: These are measured by the increase in the net income from agricultural lands or increase in land values resulting from higher yields or lower production costs through reduction in the moisture content of the soil (exclusive of excessive moisture due to flooding), and the increase in the value of urban and industrial lands due to improvement in drainage conditions.

PROJECT COSTS

Estimating project costs for comparison with benefits involves determining the cost necessary to establish and operate the project; and incorporating this with other costs such as loss of land yield from otherwise higher uses, into an estimated overall economic cost. Taken into account are the period during which costs are to be incurred, interest charges, amortization of investments during the specified period, salvage value, and similar factors. The estimated economic cost is expressed in equivalent average annual terms to permit direct comparison with estimated benefits similarly expressed.

a. Economic Expenditures. The first cost of a project is considered to include:

(1) The expenditure, subsequent to the authorization of the project by Congress, of labor, materials, and equipment necessary to plan, design, and construct the project.

(2) The costs of land and rights of way on which the project is located or which are required for construction and operation.

(3) The compensation for damages, relocation of structures and facilities, any remedial measures, and all other adjustments expected to be made in connection with the project.

b. Interest, Amortization, Replacement, Operation and Maintenance. An estimate is made of the period the project will be needed for the intended purposes. Even though a project might have a longer useful life, the life used for purposes of economic analysis is limited to a maximum of 100 years or in some cases to 50 years as previously mentioned. The computation of an annual charge includes interest, amortization of the initial investment, and cost of maintenance and operation. The equivalent annual charges, "economic costs," are compared with the average annual benefits to show the economic value of the project.

The maintenance, operation, and administration of a project includes all other costs which are expected to be incurred during the assumed useful economic life of the project in order to utilize it for the intended purposes. Also included are the estimated costs of the major, as well as minor, replacements of portions of the project which are expected to have useful physical lives less than the assumed economic life of the total project.

c. Non-Monetary Costs. In addition to the costs just described there are also costs which are not necessarily accounted for in the monetary evaluation. These costs include adverse environmental and social effects such as loss of scenic or historic values of land or property acquired for the project, the loss of accumulated "good will" or "established market values" involved when a business enterprise must move to a new location, and other consequential damages. The National Environmental Policy Act of 1969 requires that environmental impacts be considered. In appropriate cases, such consideration may conclude that the project should not be undertaken, should be delayed, or should be limited in scope to avoid destroying the values involved. In addition to economic adversities, Section 122 of the 1970 Rivers and Harbors Act also requires that adverse environmental and social impacts of plans and projects be considered in project evaluation. Specifically, Corps projects are to be planned to eliminate or minimize possible adverse economic, social and environmental effects.

d. Adverse Effects and Associated Costs. Associated costs are costs other than those involved directly in establishing, maintaining, and operating the project, but necessary for realization of certain benefits of the project. Associated costs are deducted from the benefit estimates. The costs of a project are measured by the estimated expenditure of goods, services and intangibles to establish, maintain and operate the project. Costs include expenses incurred to mitigate against damages or detriments of a primary nature resulting from a project. This does not imply that all adverse effects must be directly mitigated. It is

the U.S. Government policy that enhancement of fish and wildlife and environmental quality are treated as an objective of Civil Works projects. Project cost include costs of such enhancement.

COMPARISON OF BENEFITS AND COSTS

A carefully accomplished benefit-cost evaluation in which it is shown that the benefits to be yielded by the project would not be more economically obtained in some other way should enable the Nation to determine whether it will be better off if it undertakes a contemplated public investment. While this ideal of analysis in support of public decision-making may not be fully met in all Federal water resources planning, it nonetheless is more closely approached in this area than it is most other areas of contemplated public investment.

The ratio of benefit to costs, for any proposed undertaking, is a significant, but approximate, indicator of its efficiency. It serves a purpose similar to the return on investment used in the private business when expansion of facilities is contemplated. Costs and damages can be determined in monetary units and are usually computed at present-worth values and then amortized over the period of analysis. Benefits may be either tangible (capable of expression in dollar terms) or intangible. Tangible benefits, as they are expected to occur, are brought back to present worth by a given interest rate factor and then amortized to obtain average annual benefits. The benefit-cost ratio is derived from dividing average annual benefits by average annual cost and is the economic indicator of project worth. With a project of given constant costs, increases in the discount rate have a significant depressing effect on the

benefit-cost ratios regardless of future benefit growth rates. However, it is significant to note that the depressing effect is most adverse in those situations where benefit growth rates are of a deferred nature i.e., when benefits largely accrue in later stages of project development and operation.

The recently promulgated Principles and Standards provide for the evaluation of proposed water projects in the light of two national objectives, namely, national economic development and environmental quality. Under the P&S public information accounts, setting forth the effects of proposed projects on national economic development, environmental quality, social well-being, and regional development, are to be provided. These Federal guidelines became effective 25 October 1973.

SUMMARY AND CONCLUSION

In spite of the difficulty of quantifying economic losses due to the weed menace, there is little doubt that direct losses are very great. Indirect losses may be more severe but cannot be readily identified and certainly not quantified.

The problems associated with aquatic weeds -- and particularly transportation, navigation, and schistosomiasis -- are growing as water patterns in developing countries are manipulated through dam construction and other man-made changes to the environment. Also, increasing sewage effluent and other by-products of an expanding population will probably add to the severity of the problems.

The magnitude of economic losses resulting from the presence of aquatic weeds and eradication and control costs justifies further research on means for controlling the spread of weeds in these countries. Such research should be directed toward (1) improving the effectiveness of mechanical, chemical, and biological control methods in a region, and (2) identifying the optimum combination of these control methods for a specific situation.

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Table 1 Watershed Work Areas and Estimated Expenditure FY 78

BOARD OF COUNTY COMMISSIONERS OF CITRUS COUNTY

Area	Total Cost	Hydrilla	Waterhyacinth
Lake Tsala Apopka	$ 81,000	$ 61,000	$20,000
Crystal River Canals	130,000	130,000	
Crystal River	269,000	259,000	10,000
TOTAL	$450,000	$450,000	$30,000

GAME AND FRESH WATER FISH COMMISSION

Area	Total Cost	Hydrilla	Waterhyacinth
St. Johns Basin	$ 10,000		$ 10,000
Oklawaha River	2,000		2,000
Oklawaha Lakes	110,000	$100,000	10,000
Suwannee	75,000	15,000	60,000
Alafia-Manatee	79,000	44,000	35,000
Lake Istokpoga	53,000	8,000	45,000
Lake Trafford	106,000	4,000	102,000
Peace River	54,000	20,000	34,000
Myakka River	54,000	25,000	29,000
Nassau	7,300		7,300
Aucilla-Wacissa	15,000	10,000	5,000
West Coast Basin	65,000	40,000	25,000
East Coast Basin	1,000		1,000
TOTAL	$631,300	$266,000	$365,300

Table 1 (Continued)

BOARD OF COUNTY COMMISSIONERS OF HIGHLANDS COUNTY

Area	Total Cost	Hydrilla	Waterhyacinth
Lake Istokpoga 70-30%	$77,000	$72,000	$5,000

HILLSBOROUGH COUNTY MOSQUITO CONTROL DEPARTMENT

Area	Total Cost	Hydrilla	Waterhyacinth
Hillsborough River 70-30%	$52,000	$22,000	$30,000

LAKE COUNTY WATER AUTHORITY
(Includes the Oklawaha Basin Reclamation and Water Control and Conservancy Authority)

Area	Total Cost	Hydrilla	Waterhyacinth
Oklawaha River 70-30%	$ 8,000	$ -0-	$ 8,000
Oklawaha Basin Lakes 70-30%	85,000	75,000	10,000
TOTAL	$93,000	$75,000	$18,000

LEE COUNTY HYACINTH CONTROL DISTRICT

Area	Total Cost	Hydrilla	Waterhyacinth
Caloosahatchee River 100%	$75,000	$50,000	$25,000

Table 1 (Continued)

BOARD OF COUNTY COMMISSIONERS OF ORANGE COUNTY

Area	Total Cost	Hydrilla	Waterhyacinth
St. Johns Basin Lakes 70-30%	$354,000	$349,000	$ 5,000

BOARD OF COUNTY COMMISSIONERS OF POLK COUNTY

Area	Total Cost	Hydrilla	Waterhyacinth
Lake Pierce 70-30%	$165,000	$150,000	$ 15,000
Polk County Lakes 70-30%	193,000	119,000	74,000
TOTALS	$358,000	$269,000	$ 89,000

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Area	Total Cost	Hydrilla	Waterhyacinth
Kissimmee River Tributaries 70-30%	$ 350,000	$ 230,000	$120,000
Okeechobee Basin Minor Tributaries 70-30%	189,000	176,000	13,000
Kissimmee River Main Channel 100%	600,000	450,000	150,000
Lake Okeechobee 100%	266,000	266,000	-0-
TOTALS	$1,405,000	$1,122,000	$283,000

Table 1 (Continued)

SOUTHWESTERN FLORIDA WATER MANAGEMENT DISTRICT

Area	Total Cost	Hydrilla	Waterhyacinth
Gulf Coast - 70-30%			
Anclote River	$ 4,000	$ 4,000	$ -0-
Lake Tarpon	4,000	1,000	3,000
Medard Reservoir	6,000	2,000	4,000
Homosassa River	41,000	38,000	3,000
Chassahowitzka River	4,000	3,000	1,000
Weekiwachee River	20,000	18,000	2,000
TOTALS	$ 79,000	$ 66,000	$ 13,000
Withlacoochee - 100%			
Lake Panasoffkee	$ 20,000	$ 12,000	8,000
Withlacooche River	486,000	344,000	142,000
TOTALS	$506,000	$356,000	$150,000

Source: Bureau of Aquatic Plant Research and Control FY 1978-79, Tallahassee, Florida

Table 2 Water Work Areas and Estimated Expenditure

AGENCY	LOCAL FUNDS	STATE FUNDS
Lee County Hyacinth Control District	184,030	55,209
Melbourne-Tillman Drainage District	65,747	19,725
Sumter County	9,615	2,885
Indian Trail Water Control District	78,777	23,633
Collier County	165,000	49,500
Greenacres City	2,031	609
Coral Springs Improvement Districts	49,682	14,905
Sunshine Drainage District	77,185	23,156
North Lauderdale Water Control District	25,592	7,677
Seminole Water Control District	20,580	6,174
Broward County	66,667	20,000
Brevard County	101,351	30,405
Charlotte County	50,000	15,000
Indian River Farms Water Management District	106,001	31,800
Manatee County Mosquito Control	38,555	11,567
Highlands County	41,690	12,507
Bailey Drainage District	7,692	2,308
Hollywood Reclamation District	91,442	27,433
West Lauderdale Water Control District	26,154	7,846
Margate	103,260	30,978
Orlando	45,708	13,713
Palm Beach County	86,445	25,933
Central Broward Drainage District	115,806	34,742

Table 2 (Continued)

AGENCY	LOCAL FUNDS	STATE FUNDS
Altamonte Springs	40,342	12,103
West Palm Beach	41,546	12,464
Spring Lake Improvement District	20,070	6,021
North Springs Improvement District	13,755	4,126
Central County Drainage District	21,222	6,367
Ft. Pierce	21,896	6,569
Tamarac	36,781	11,034
Gerber Groves	33,077	9,923
Sebastian River Drainage District	25,572	7,672
Dade County	1,067,678	320,303
Coconut Creek	5,077	1,523
Palm Beach Gardens	47,475	14,242
Martin County	20,506	6,152
Ft. Pierce Farms Water Control District	17,803	5,340
Loxahatchee Sub-Drainage District	29,522	8,857
Juno Beach	1,492	448
Dunedin	10,517	3,155
Pinellas County	78,151	23,445
Lauderdale Lakes	58,266	17,480
Hobe-St. Lucie Conservancy District	47,885	14,365
Fellsmere Water Control District	65,070	18,622
St. Johns River Water Management District	54,615	16,385
Volusia County	36,496	10,949
Lake Worth Drainage District	398,178	119,453

Table 2 (Continued)

AGENCY	LOCAL FUNDS	STATE FUNDS
Acme Improvement District	33,043	9,913
Barron Water Management District	34,000	10,200
City of Atlantis	2,942	883
St. Petersburg	322,684	96,805
Miramar	4,231	1,269
Oakland Park	13,192	3,958
Indiantown Drainage District	6,769	2,031
Troup-Indiantown Water Management District	10,769	3,231
Polk County	27,636	8,291
Cape Coral	32,000	9,600
East County Water Control District	123,077	36,923
North Port Water Control District	49,231	14,769
Sarasota County	192.729	57,818
Orange County	116,667	35,000
Hastings Drainage District	23,346	7,004
Bay County	----	200,000
Lake Clark Shores	4,073	1,222
Manatee County Board of Commissioners	136,358	40,907
South Florida Water Management District	----	184,661
Southwest Florida Water Management District	----	78,893

Source: Bureau of Aquatic Plant Research and Control, FY 1978-79. Tallahassee, Florida.

Table 3 Direct and Indirect Benefits of Aquatic Weed Control in Louisiana

DIRECT CLIENT BENEFITS

Sport fishermen	1,400,000		
Boaters	75,000	30%	250,000
Comm. fishermen	10,000	50%	20,000
Trappers	2,000	80%	20,000
Propt. owners	375,000	50%	750,000
Waterfowl hunters	24,400	20%	122,000
Farm pond owners	15,000	50%	30,000
Livelihood	7,000	20%	35,000
Potable water supply	193,340	60%	276,200
Water oriented	210,000	20%	1,050,000
	2,311,740		

INDIRECT CLIENT BENEFITS

Navigation	maintaining navigable waters
Agribusiness	irrigation and drainage
Municipalities	drainage and flood control
Oil and Gas	exploration and oil field use
Industries	cooling and fire protection
General Population	control of waterborne vectors of diseases

250,000

2,311,740
250,000

2,561,740

BUDGET 77-78/CLIENTS

$1,525,395 2,561,740 = 0.5954523

Source: Lee. Aquatic Weed Control, Some Consideration of Importance. Annual Meeting of the Aquatic Plant Control Research Program. U.S. Army Corps of Engineers 1977.